Medical Applications for RIA

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Outline

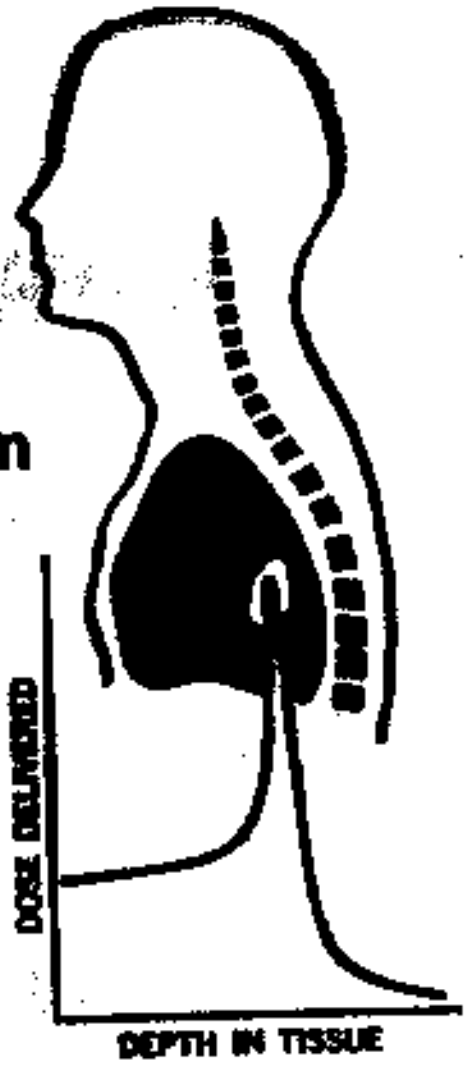
- Medical applications of nuclear techniques: Radiation
  - "Internal" radiation – radioisotopes
  - "External" radiation – beams
- Bottom line for RIA
  - Isotopes – a natural!
  - External beam radiation – less obvious, needs further discussion
- Methodology
  - Describe application
  - How could RIA be relevant?
  - Requirements for a successful Applications program at RIA
  - Impact on "mainstream" programs of RIA
  - Assessment, definition of appropriate role for RIA

External Beam

- **Applications: Radiotherapy, radiobiology**
  - Bragg-peak, deep penetration
- **Requirements for accelerator, facility parameters**
  - Energy (therapy): to 400 MeV/amu – RIA fine
  - Energy (space-radiation effects) at least 1 GeV/amu – above RIA range
  - Ions: carbon (therapy); protons – uranium (biology) – RIA not taxed
  - Flux: 10^9 or less per second – really cutting back!
  - Capabilities of producing large, tightly controlled and uniform beam sizes ≈ 20 cm diameter, ± 2% uniform flux
  - Dedicated experimental area, proximity to clinical facilites

THERAPY

with External Ion-Beam



External Beams

- **Requirements for successful application program**
  - * Therapy:
    - Must have well-equipped treatment room with adequate patient and medical support areas
    - Must have access > 40 weeks per year, 4-5 days/week, at least 8 hours per day
  - * Radiobiology:
    - Good experimental area with appropriate support facilities including animal, cell preparation and holding rooms, staging areas
    - Experimental area must have flexible sample holding, irradiation cell capabilities, with good dosimetry, control systems
    - Access to beam in week-or-two blocks, probably 6 blocks/year

External beams

- **Impact on "mainstream" programs:**
  - Would be very disruptive unless effective multi-user capabilities of driver were possible (i.e. such medical/biological programs could be truly parasitic)
  - Scheduling problems might occur depending on time-sharing constraints (beam-compatibility conditions)

External Beam: Role for RIA

- **A therapy program would be impractical!**
  - Even if time-sharing were built in, and dedicated treatment area were available, unlikely RIA would be running in long contiguous blocks needed for therapy
  - Cost of beamtime, unless truly parasitic (and free!) would be a deterrent
- **Radiobiology fit is somewhat better.**
  - Must be completely parasitic
  - Community does not have large resources to pay for beamtime or facilities, these would have to be provided for
  - Community is not large or powerful, probably not much benefit to RIA by bending over backwards to accommodate such a program
- **… A long shot!**

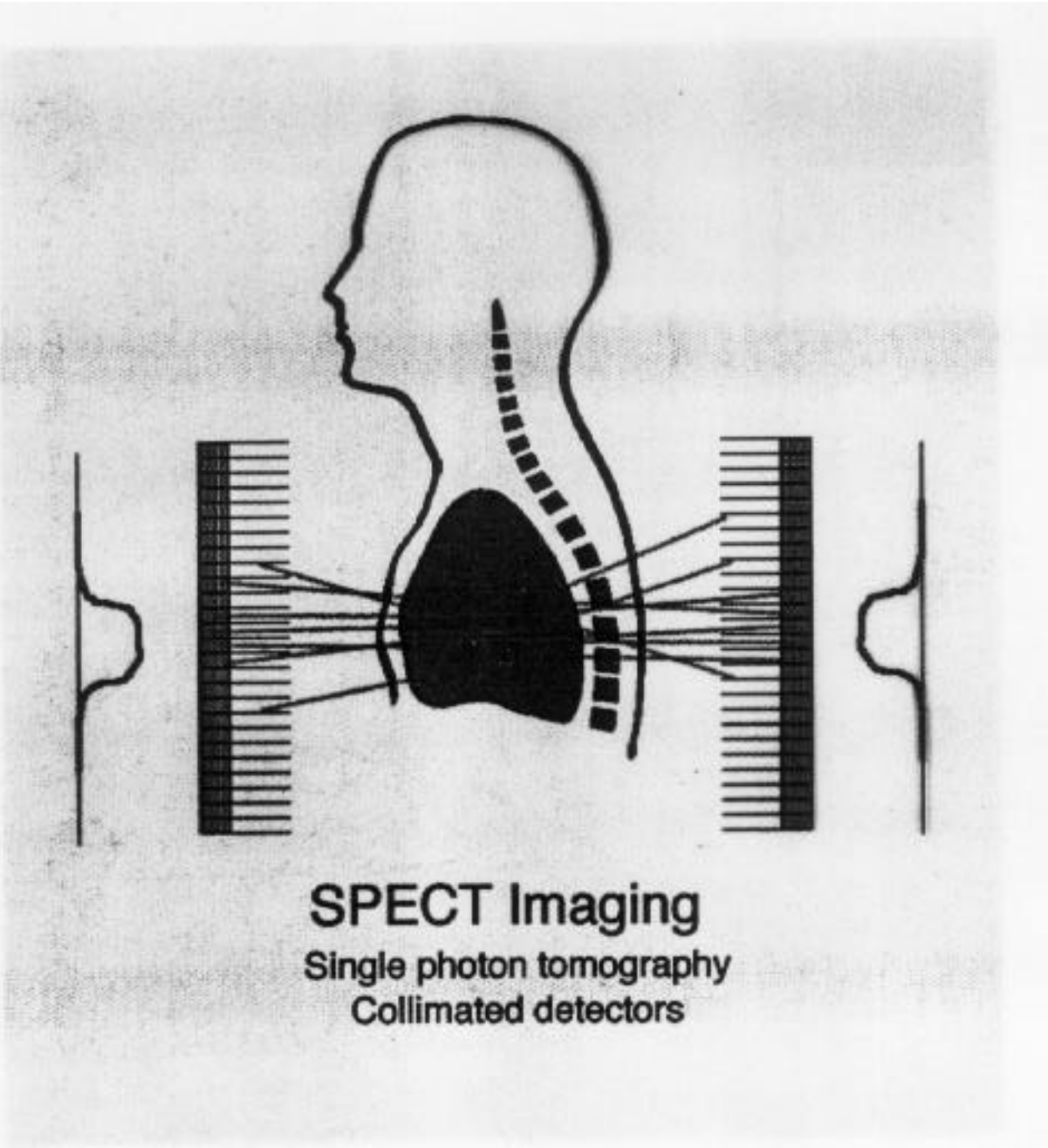
Radioisotopes: Diagnostic, Therapeutic

- **Very large business:**
  - >$10B per year in nuclear-medicine procedures
- **Certain nuclear properties sought**
  - Reasonable halflife – delivery time, treatment/procedure duration
  - Characteristics of radiation – different for diagnostics or therapy
- **Logistics and costs are STRONG drivers**
  - ^{99}Tc/Mo is well-established as diagnostic of choice for SPECT
    * Excellent supply lines with redundancies
    * Cost down to few cents per mCi
  - PET isotopes (^{11}C, ^{18}F, ^{15}O, …) mainly provided by small cyclotrons close to point-of-use (automated chemistry)
  - Specialized applications, therapy STILL OPEN TO OPTIMIZATION
    * Many desirable isotopes are much more expensive, >$1/mCi, due to chemistry complexity, accelerator costs, distribution costs, …
  - Strong need for R&D activities…

Basic Considerations: Diagnostic Applications

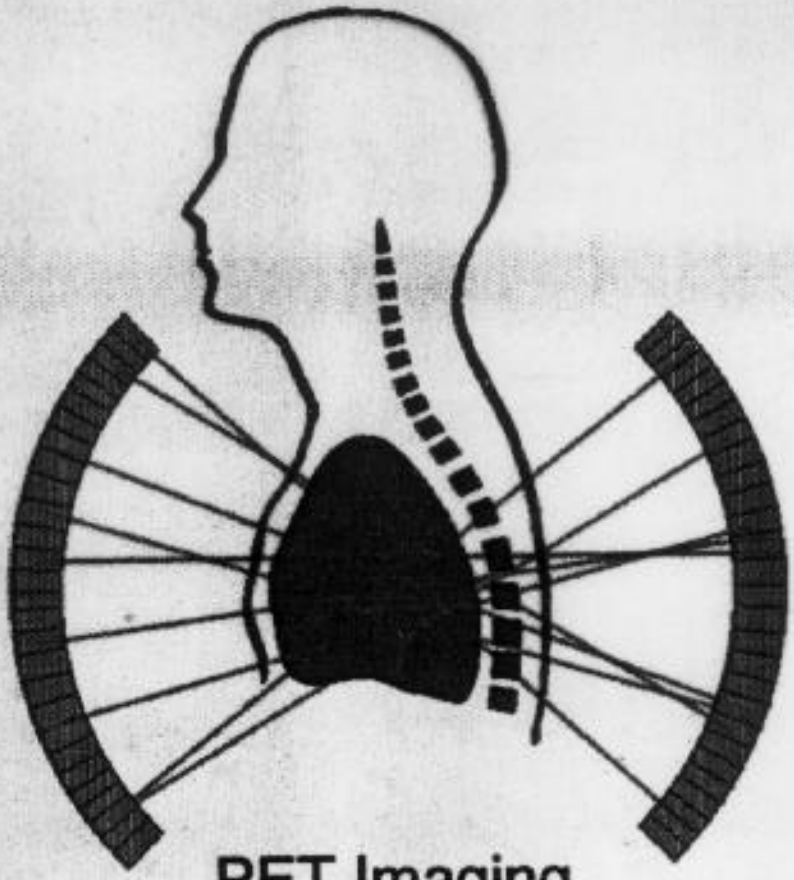
Desirable isotope characteristics

- Maximize external detection efficiency
  - Photon emission: gamma, x-ray, 50 keV – few MeV
- Minimize dose to patient
  - "Pure" radiation: no alpha, no beta, low gamma fraction other than desired line
  - Optimize halflife: long enough to enable uptake in site to be studied, short enough to deliver low dose after end of study



SPECT Imaging

Single photon tomography
Collimated detectors



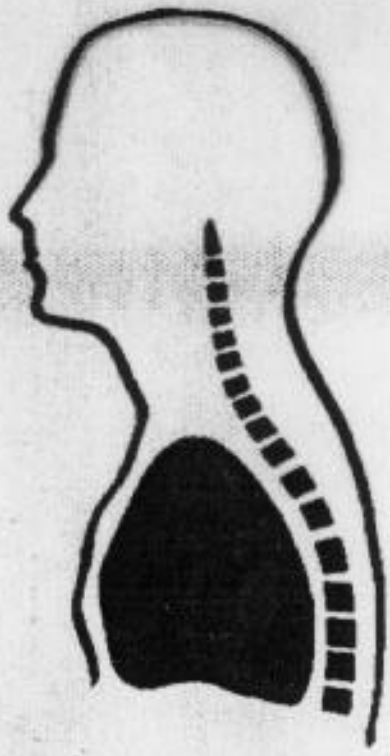
PET Imaging

Coincidence spectroscopy
of 180° annihilation radiation
(511 keV)

Basic Considerations: Therapeutic Applications

Desirable isotope characteristics

- Maximize local dose (in desired treatment area)
  - Short-range radiation (alpha, beta, low-energy photon)
- Minimize dose outside of desired treatment area
  - Low gamma component
- Halflife tailored to treatment type



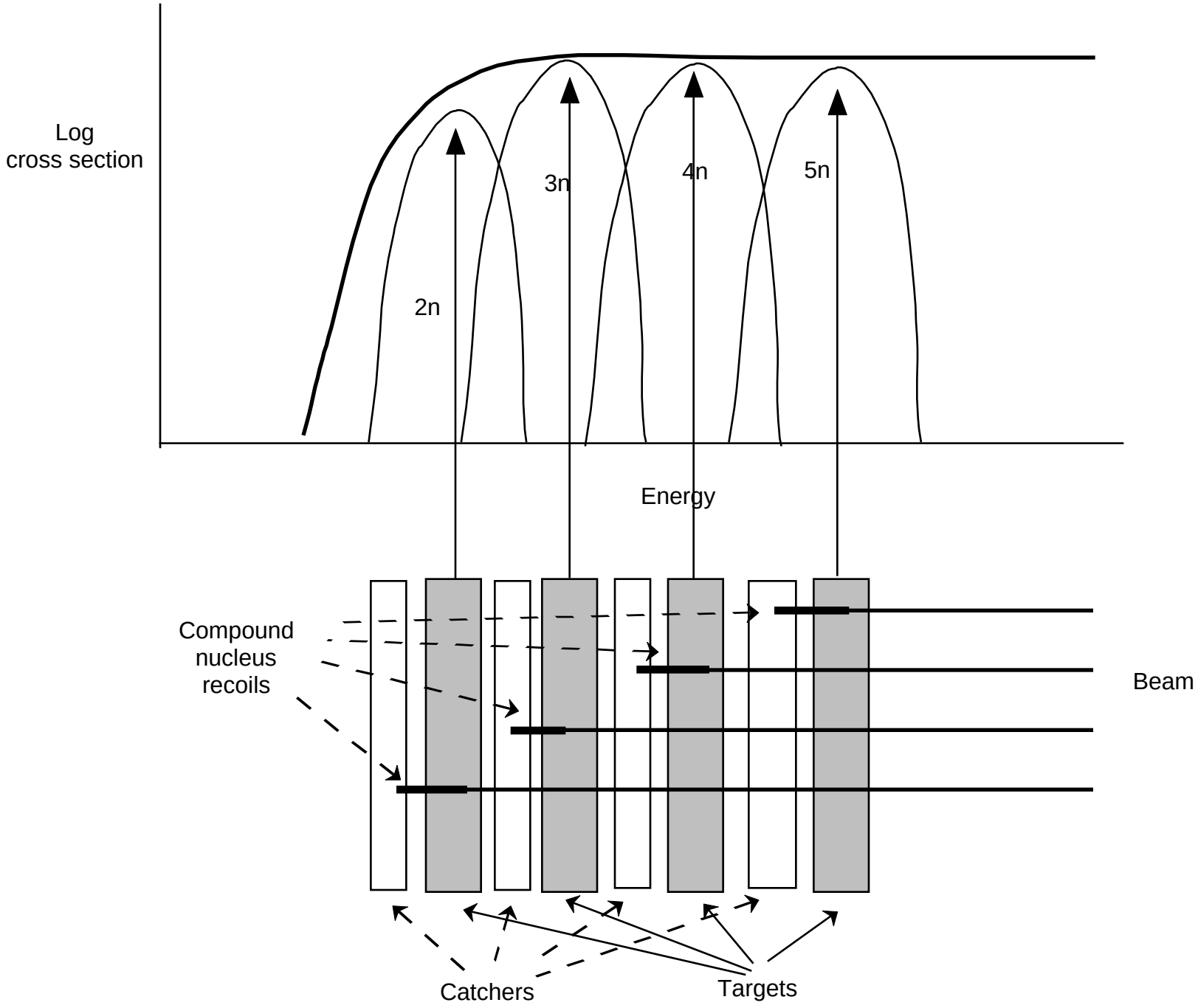
ISOTOPE THERAPY

- Tumor-seeking radiopharmaceuticals
- Short-range (e.g. α, β) radiation

Requirements for RIA

- **In many ways, heavy-ion accelerator is ideal for medical isotope production**
  - "Alchemy" with beams offers great simplification possibilities in target selection (refractory – heat-supporting, chemistry, …)
  - Compound-nucleus reactions, with well-defined energy-dependent channels, hence "physical" separation with easier (or no) chemistry
  - Kinematics from recoiling compound nuclei provide natural selection/separation from target
- **Problem has always been that heavy-ion accelerators never possessed beam currents adequate for commercial production of isotopes**
  - RIA is the first heavy-ion "blowtorch"
  - Milliampere level carbon-oxygen beams now available from modern ECR sources

(HI, xn) Excitation Functions



Requirements

- **Beam energy 5-7 MeV/amu**
  - Peel beam off from first stages of Driver
  - Note: could use full-energy, and fragment separator, but probably not much use in the long run for medical isotope production
- **Facilities:**
  - Hot cells,
  - Heavily shielded target areas (but nothing like ISOL facility requirements)
- **Requirements for successful applications program:**
  - Continuous, uninterrupted access to isotope, once a clinical or research program is underway
  - For research application, continuous availability may not be so necessary, but supply must be *predictable* and reasonably consistent
  - Program MUST BE PARASITIC (i.e. multi-user capability a MUST)

Appropriate role for RIA

- **RIA should NOT get in mode of being commercial supplier of isotopes**
  - Cannot guarantee availability on commercial scale
  - Unlikely that cost, even in truly parasitic mode, could yield commercially competitive products

- **RIA would EXCEL as a research tool for new production techniques, isotope yields, targeting techniques, …**
  - Accessibility to vastly expanded array of isotopes
  - New, novel ways of producing existing commercial isotopes with possible cost-reduction techniques
  - Economical production of new isotopes, previously too expensive or inaccessible

Role for RIA (Cont.)

- **Could produce batches of isotopes for small-scale clinical research programs, under carefully planned conditions**
- **Technology prototype for dedicated, low-energy heavy-ion production facilities**
- **Radioisotope community is large, strong**
  - Looking for new technologies, cost-reduction techniques
  - Very cost-conscious – i.e. economics drives success!
  - RIA offers exciting possibilities that should pique the interest of this community

Summary

- **External beam medical applications of RIA are less likely to become substantial programs**

- **Radioisotope research is VERY worthwhile to pursue**
  - Definite plans should be made for a low-energy target station, fed by beams in the 5-7 MeV/amu energy range, as part of the Driver configuration